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Stereophonic and two-channel sound in terrestrial television broadcasting

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Summary

During the 1970's and early 1980's, the possibility of adding stereophonic sound to existing television services has found increasing interest and support. A number of possible methods exist for the transmission and reception of the additional sound signal required for stereo and some of them are also suitable for the transmission of independent sound signals, such as may be required for a bi-lingual service. The BBC has investigated several of these possibilities and these are described in the Report. The most recent tests are of a two-carrier system, similar to that now used in West Germany, but modified to suit U.K. System I television. The early trials of this system have revealed a state of affairs somewhat less optimistic than had been expected; the results, so far, indicate that there may be difficulty in providing a signal that would be both compatible with existing receivers and able to provide a two-channel service over the existing coverage area. Further investigation will be necessary before a final decision can be reached.

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1. Introduction

For many years there has been interest in the possibility of adding stereophonic (stereo) sound to existing television services. Opinions vary as to the realism and value of stereo sound with television but there is little doubt that it has found increasing support during the late 1970s and early 1980s. The artistic problems of producing stereo sound signals that relate realistically to a small television picture showing close-ups, wide-angle shots, panning shots etc. are clearly both considerable and interesting but are too extensive to be considered here.

At the receiver there is little scope for variation. The photograph in Figure 1 shows one example of a prototype cabinet produced by a British manufacturer; separate loudspeakers to give a wider sound stage are a possible variation on this arrangement and it has also been suggested that a loudspeaker located behind the viewer could be used.

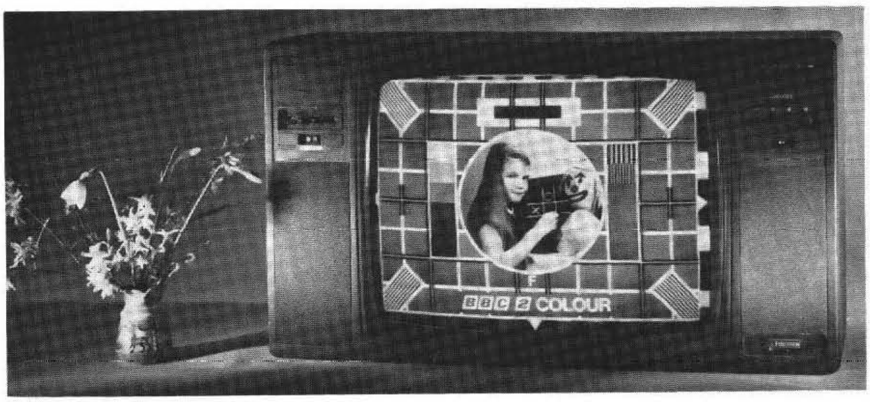

Fig. 1 - Commercially manufactured prototype television receiver with two-channel/stereo sound

A number of possible methods exist for the transmission and reception of the additional sound signal required for stereophonic operation and some of these are also suitable for the transmission of independent sound signals, such as may be required, for example, to provide a bi-lingual service. The possibilities investigated by the BBC include

1) Pilot-tone sound (as used for stereo radio broadcasting). (1)

2) FM-FM sound (as used in Japan). (2,3)

3) Two-carrier sound (as used experimentally in West Germany. (2,4,5)

4) Digital sound (as proposed for use in satellite television broadcasting). (6)

2. Pilot-tone Sound System

The Pilot-tone stereo system used for v.h.f. radio broadcasting appeared to be such an attractive proposition for television sound that an investigation was carried out to assess its feasibility. The signal parameters used in the investigation were similar to those used in v.h.f. Band II radio broadcasting, except that the frequency-deviation was limited to ± 50kHz instead of ± 75 kHz, to maintain compatibility with existing television sound standards. Only stereo operation could be contemplated because the relatively poor separation of the pilot-tone stereo system would rule out the use of independent channels for bilingual or separate programmes. In an initial investigation of compatibility, it was found that the introduction of a pilot-tone stereo signal produced no detectable impairment to the picture or the sound on a number of television receivers, provided that the modulation did not seriously over-deviate the fm sound carrier. In a further preliminary experiment, it was found that the standard 38 kHz subcarrier could not be used because of intermodulation with components at line-frequency causing intolerable interference to reception, mainly due to whistles at 5.76 kHz and 8.875 kHz (38 kHz minus twice line-frequency and three times line-frequency minus 38 kHz, respectively). Work from this point onwards, therefore, employed signals with a subcarrier frequency equal to twice television-line-frequency; in this case the interfering whistles did not appear, but severe 'buzz-on-sound' remained, due to interference from the vision signal.

The prospect of stereo sound for television naturally raises expectations of improved sound quality (7) and it is worthwhile digressing at this point to discuss the effects of buzz-on-sound interference in television because of its special

importance in this case. Buzz-on-sound can arise in a number of ways (7,8) and the main causes may be listed:

a) Phase-modulation of the received vision carrier due to the receiver vestigial-sideband (v.s.b.) amplitude-response, as explained further below.

b) Phase-modulation of the f.m. sound signal due to variations in receiver circuit impedances caused by the vision signal.

c) The effects of receiver non-linearity on video signal components at sub-harmonics of 6 MHz, causing interference to the 6 MHz intercarrier signal.

d) Mixing of chrominance components with video signal components, causing interference to the 6 MHz intercarrier signal.

e) Unwanted audio-frequency interfering signals generated by various less well-defined mechanisms within television receivers.

f) Unwanted frequency-modulation of the local oscillator.

In addition, over-modulation of the vision transmitter can cause severe problems and careful operation by the broadcaster is necessary for this reason. Multipath propagation also can cause over-modulation of the received vision signal due to a reduction in the level of the carrier relative to the sidebands. More common is the effect whereby multipath propagation is found to cause variations in some of the effects listed above, by altering the relative levels of the received vision and sound carriers. Most, if not all, domestic television receivers use intercarrier sound reception and, with this kind of receiver, items (a) to (e) inclusive can all cause buzz-on-sound interference. It is sometimes suggested that so-called split-carrier sound receivers working on the conventional superhet principle could be used to alleviate buzz problems, but such receivers would still be liable to some buzz interference, mostly under items (b), (e) and (f). The design requirements would be very severe. In the U.K., the receiver would have to be tunable over the u.h.f. band and a typical tuning voltage range might be of the order of 20v. Unwanted f.m. of the local oscillator would need to be less than ± 40 Hz for a buzz level of about −60 dB and unwanted audio-frequency fluctuations of the tuning voltage would therefore have to be kept to less than ± 2μv*. Even if this problem could be solved, split-carrier receivers would still suffer from difficulties from (b) which seem very hard to handle. Remembering the aim to achieve high-quality sound reproduction at reasonable cost, only intercarrier reception was considered, therefore, in this investigation.

*The design problem would be less severe in a v.h.f. television receiver.

Turning again to the problem of developing an experimental receiver for pilot-tone stereo sound, it was found that unwanted phase-modulation of the vision carrier due to the use of v.s.b. reception (item (a) above) was the main cause of the very severe buzz-on-sound that was encountered. Unwanted phase-modulation of the carrier arises due to the asymmetry of the receiver v.s.b. response leading to unequal vision sidebands. The higher the frequency of the vision carrier modulation, the greater is the difference between the levels of pairs of sidebands and the greater is the phase-modulation of the vision carrier due to this difference; there is thus a triangulation effect, with higher levels of phase-modulation occuring at the higher sideband frequencies.

The phase-modulation is transferred as interference to the sound signal through the intercarrier process where it is the value of unwanted f.m. that determines the level of the interference. The f.m. component is proportional to the rate-of-change of carrier phase and the overall unwanted f.m. is hence proportional to the square of the vision sideband modulation frequency; i.e. there is a double-triangulation effect. This means that, at the stereo subcarrier frequency, the interference power level will be some nine times the level at 10 kHz and several thousand times that at 250 Hz. Thus, whilst this effect may be only minor with normal monophonic television sound reception, it can and does produce intolerable interference in the difference-channel of a pilot-tone stereo receiver. To avoid this problem, an experimental inter carrier sound receiver was built using a double-humped i.f. response which was symmetrical at vision carrier frequency. Although the results obtained showed a great improvment, they were only just acceptable for normal television reception and unacceptable for the hi-fi application required for stereo, despite great care and elaboration in the design.

Consideration was also given to the compatibility of pilot-tone stereo sound with existing planning. It was found that co-channel protection ratios were likely to be affected adversely, probably by more than 10 dB. Moreover, in the UK and elsewhere, the use of $\frac{5}{3}$ - line - frequency offset working is very common and this could give rise to audible whistles in the stereo difference channel. As a result of these various difficulties, attention was

turned to the two-carrier sound system, described later. It is of interest to note that work on the pilot-tone method is continuing in the USA, in conjunction with 525/60 system M television (9).

3. FM-FM Sound System

In the FM-FM sound system (2,3), the second sound channel is provided by an f.m. subcarrier with a rest-frequency of 31.5 kHz (chosen to equal the second-harmonic of the line-frequency to reduce interference from the picture into the second sound channel). A control subcarrier at 3.5 times the line-frequency (55.125 kHz) is amplitude-modulated by tones to indicate to the receiver whether mono, stereo or two sound programme signals are being transmitted; for stereo, the f.m. subcarrier is used to carry the difference or 'S' component. The principle transmission characteristics of the FM-FM system may be found elsewhere (2), but Figure 2 illustrates the main features.

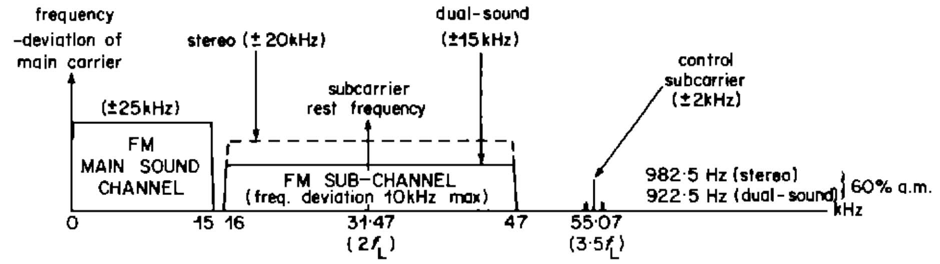

Fig. 2 - FM-FM system baseband spectrum

This system has been used in Japan since late 1978. Its use was considered by several broadcasters in Europe in the early 1970s, but it was found (2) that the two-carrier systems described below was slightly better than the FM-FM system under conditions of multipath reception such as are found in mountainous regions. The FM-FM system had also been found to have a lower signal-to-noise ratio than the two-carrier system.

In addition, more serious difficulties can arise when channels are shared using offset carrier frequencies. It has been shown (10) that, with co-channel interference but without offset operation, a difference of at least 10 dB exists between the signal-to-noise ratios of the first and second channels and that this difference can worsen to 20 dB in the case of an unfavourable offset condition. There are some offset conditions under which the sound signal-to-noise ratio can be severely impaired, although the picture impairment is almost imperceptible.

Therefore, although the Japanese FM-FM system is used in service, it has not been tested practically by the BBC because it does not appear to have sufficient potential as a hi-fi system.

4. Two-carrier Sound System

A two-carrier sound system has been developed in West Germany (2,4,5). The additional sound carrier is used to carry either additional stereo signal information or a second language. The principle characteristics of the two-carrier system may be found elsewhere (2), but Figure 3 illustrates the main features. It will be seen that, whereas the first (main) sound carrier is used to carry the compatible mono component, $M = \frac{L + R}{2}$, as normal, the second carrier does *not* carry the S (stereo difference) signal but the R (right-hand) signal instead. This form of signal composition was chosen because, in the presence of coherent interference from the vision signal (buzz-on-sound, as described earlier), it ensures that similar correlated interfering signals appear equally (centre-stage) on the recovered stereo (L and R) signals, rather than predominantly to one side and at a higher level. As in the FM-FM system, a control subcarrier is carried by the main sound carrier and used to identify the kind of transmission as monophonic, stereophonic or double-sound.

Reception of the second sound carrier can be achieved simply by the use of an additional intercarrier amplifier/demodulator, tuned to the new intercarrier frequency (4). However, the use of stereo sound is leading to demands upon receiver

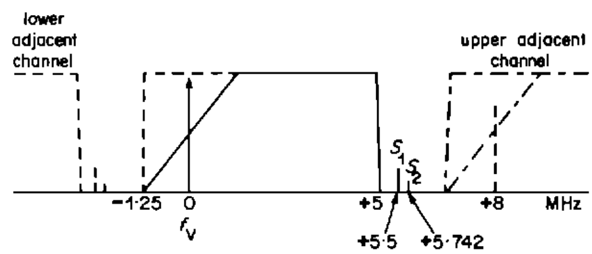

Fig. 3 - Two-carrier system: rf spectrum system G (uhf)

circuitry for sound signals of much higher quality than is normally found in television receivers and improved methods and standards of reception are being developed (8,11).

A spectral arrangement of the two-carrier method adapted to suit the U.K. System I would appear similar to Figure 3 but, because of the greater bandwidth of the vision signal, the additional sound carrier would need to be spaced about 6.3 MHz from the vision carrier. The relative levels of the vision and sound carriers, and the frequency-spacing between the two sound carriers, have to be chosen to give good compatibility with existing receivers, whereby interference to the picture or main sound channels is kept to a minimum. As a further precaution, the detailed frequency-spacing between the vision carrier and the additional sound carrier needs to be chosen so as to reduce the visibility of any interference. This is a useful precaution, even when f.m. carriers are used as here, because the visibility of interference patterns tends to be greatest when the sound carriers are unmodulated.

Initial laboratory tests indicated that a System I version of a two-carrier system appeared to be feasible and two over-air compatibility tests were therefore carried out, using the BBC-2 transmitter at Crystal Palace after closedown of the normal programme. Both tests used the transmitters at one-quarter of their normal radiated powers and were appraised by about eighty BBC engineers using their own domestic receivers. The first test, carried out in mid-1981, revealed that the chosen spacing of 0.26 MHz between the second and main sound carriers was insufficient to provide adequate protection against interference to sound reception in some existing receivers; the level of interference would have been somewhat intrusive in the case of, say, dual-language operation (where the modulations of the two sound carriers would be substantially unrelated) but imperceptible with stereo operation (where the modulations would be strongly correlated). In addition, some viewers reported patterning on the received picture.

The first over-air test thus revealed a state of affairs that was less optimistic than had been indicated by either the initial laboratory tests or the reports of work in West Germany (2,4). The signal parameters were, therefore, modified. To reduce the crosstalk from the second sound signal into the main sound channel, the frequency spacing of the second sound carrier was increased and its level was reduced; the reduced level was also expected to reduce picture patterning. With the latter in mind, the rest frequency of the second carrier was set at 6.3046375 MHz* from the vision carrier.

At this point, it is worth noting the relative values of sound and vision carrier power used in West Germany and the U.K.

* 6.3046375 MHz $= \frac{807\ f_L}{2} - f_F$

Table 1

	West Germany (system B/G)		BBC (system I)	
	Normal (mono)	Two-channel	Normal	Two-channel (2nd tests)
vision carrier (ref.)	0 dB	0 dB	0 dB	0 dB
main sound carrier	−13 dB	−13 dB	−7 dB	−10 dB to −13 dB
second sound carrier	N/A	−20 dB	N/A	−16 dB to −22 dB

Comparison between vision and sound relative carrier levels used in West Germany and in BBC compatibility tests; vision carrier level (to sync-pulse tips) used as reference level in each case.

Table 1 includes the values used in the second test and it will be seen that reductions below the normal level of −7 dB were made in the level of the main sound carrier. This had been found necessary both from the first test and from tests made on the visibility of the intermodulation products (i.p's.) likely to be produced in transposer-transmitters. The level of the second sound carrier was varied over the range −16 dB to −22 dB. The main results and conclusions of this second test may be summarised, as follows.

i) Three main effects, buzz-on-sound, interference from the second sound channel into the main sound channel and picture patterning were all reported; several observers were affected by one or more of these impairments, the degree varying from observer to observer.

ii) Two kinds of picture patterning were observed. The first appeared at the difference frequency between the two sound carriers (approx. 300 kHz) and was uniformly distributed over the picture. The second was less noticeable and was the normal 'sound-chroma' beat between the main sound carrier and the colour subcarrier and appeared only in saturated coloured areas of the picture.

iii) Although more extensive trials are needed, the results so far suggest that, to provide a compatible two-carrier service, the levels of the main and second sound carriers might need to be as low as −10 dB and −22 dB respectively. Because of the low level of the second sound carrier, some viewers in fringe areas might not receive a sufficiently strong second sound signal; this could occur under the particular conditions of multipath interference that cause a change in the relative levels of the vision carrier and the two sound carriers. Moreover, with such a low level of second sound carrier, the design of a receiver for high-quality reception could be difficult.

5. Digital Sound

The possible adoption of digital sound for satellite television broadcasting leads naturally to its consideration for future terrestrial use. However, whereas in the case of satellite broadcasting, a digital sound signal with five or six channels can be foreseen, it is unlikely that more than two channels could be accommodated by a digital signal added to an otherwise normal terrestrial signal.

The addition of a digital sound signal would of necessity involve the addition of a carrier or subcarrier. One possibility (6) would be to use a 4-phase dpsk subcarrier, spaced at about 6.5 MHz from the vision carrier, carrying two high-quality sound signals that could be either independent or could form a stereo pair.

Practical trials would be necessary to investigate the feasibility of such a proposal and it seems likely that, once again, a compromise would have to be sought between compatibility with the existing service and good sound performance. However, experiments conducted in 1978 with a similar (sound only) 4-phase dpsk system in v.h.f. Band I (12) showed that, provided in-car (mobile) reception was not required, wide coverage could be achieved with a very modest transmitter power. Thus it might be possible to use a subcarrier of sufficiently low level, perhaps lying between −20 dB and −30 dB, to provide good compatibility. Of course, if a digital method of this kind were adopted, the existing sound carrier would become obsolescent.

6. Conclusions

In the light of developing technology, the BBC is examining ways of improving the transmission of sound with television.

One form of possible improvement is the provision of a two-channel sound system that will give both good sound reception under adverse propagation conditions and adequate compatibility with existing receivers. The search is on for such a system; the two-carrier method has been the subject of tests but further tests are required before a decision can be reached.

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